Journal of Science and Inclusive Development Vol. 4, No. 2, DOI: 10.20372/jsid/2022-119

Determination of fluoride levels and other selected physico-chemical properties in drinking water from the Duguna Fango district of Wolaita zone, southern Ethiopia

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Received: 01 November 2021; Revised: 01 May 2022; Accepted: 04 May 2022; Published: 28 June 2022

Abstract

In Ethiopia, most people use rivers, wells, and springs for drinking and other related purposes without any form of treatment. This study aimed to determine the levels of fluoride and other selected physico-chemical properties of drinking water sources in the Duguna Fango district, southern Ethiopia. Thirteen water samples were collected from different sites in Duguna Fango. The determination of the fluoride level was done by a fluoride ion-selective electrode. All other selected physico-chemical properties were measured by the standard method. Then, the results were compared with those of the specified standardized limits prescribed by appropriate organizations such as WHO (World Health Organization) and ICMR (Indian Council of Medical Research). The fluoride content was found to be between 1.14 and 4.71 mg/L, confirming that its level was exceeding the permissible limit. The average values of pH (6.32, 6.77, and 7.29); total solids (121.6, 123, and 137.89 mg/L); total hardness (186.27, 248.07, and 215.11 mg/L); and total suspended solids (103, 92.6, and 115.11 mg/L) for spring, tap, and well water samples, respectively, were found to be within the acceptable range. On the other hand, measured values of temperature (28.6, 25.3, and 31.8 ^{0}C), turbidity (30.89, 11.15, and 17.18 NTU), electrical conductivity (2280.33, 1799.53, and 2763.33 µS/cm), total dissolved solids (989.33, 735.53, and 1933.56mg/L) and total alkalinity (230.93, 221.93, and 269.67 mg/L) in spring, tap, and well water samples, respectively. From the results of this study, it can be concluded that water in the study area is not potable without removing impurities.

Keywords: Electrical conductivity, pH, Temperature, Total dissolved solids, Total solids, Total Suspended solids, and Turbidity,

Introduction

Sustainable development, food production, quality health, and poverty reduction require safe water (Reda, 2016). Also, drinking water is the second prerequisite for life, next to oxygen (Shan et al., 2013). However, third-world countries in general and Ethiopia, in particular, have suffered from a lack of access to safe drinking water from improved sources and adequate sanitation services. In Ethiopia, most people use rivers, wells, springs, and pan water for drinking and other domestic purposes without any form of treatment (WHO, 2016).

Water quality includes all the physical, chemical, and biological properties of water. According to WHO (2005), many deaths and disability-adjusted life-years worldwide are attributable to unsafe drinking water due to elevated concentrations of fluorides, heavy metals, and organic water. Fluoride ions can occur in drinking water because of the geological composition of soils and bedrock (Ayoob and Gupta, 2006). Many studies report that some parts of Ethiopia have high levels of naturally occurring fluoride that can dissolve easily into groundwater as it moves through gaps and pore spaces between rocks (Gebrekidan and Zerabruk, 2011). Depending on the concentration and consumption of its total amount, fluoride ions in drinking water have beneficial or detrimental effects. It is beneficial at low concentrations but can pose health concerns at higher concentrations (Susheela, 2018).

The elevated level of fluoride in the drinking water causes damage to the enamel of teeth (Scher, 2011). Also, it causes fluorosis. The problem of high fluoride in groundwater has now become one of the most important toxicological and geo-environmental issues in the world (Grandjean et al., 2014). Human health is adversely affected due to the presence of fluoride in excess amounts. Polluted air, water, and the food chain are responsible for excessive amounts of fluoride in the form of different compounds that can enter the human body. Fluoride ions are easily absorbed by the body from contaminated drinking water (WHO, 2006). Therefore, the use of drinking water with fluoride significantly above the WHO guideline value of 1.5 mg/L can have serious effects on health (Sabatini and Butler, 2014). Ethiopia is categorized as the most affected country by dental fluorosis and skeletal fluorosis that are associated with exposure to high fluoride concentrations in drinking water (WHO 2006, Fawell et al., 2006, Scher, 2011).

Also, properties of water like pH, temperature, electrical conductivity, total hardness, turbidity, total alkalinity, total solids, total suspended and total dissolved solids concerning water quality are accepted widely as other critical water quality parameters describing the quality of drinking water.

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In Ethiopia, access to pure drinking water is low and is estimated to be 38% (WHO, 2016). In this country, it is responsible for over 60% of the diseases that are communicable. According to the WHO, drinking water should be clear, colorless, odorless, tasteless, and free of pathogens or other toxic chemicals.

Generally, spring, tap, and well water are used as the sources of drinking and domestic consumption. However, no sufficient and documented data has been carried out on the fluoride content in spring, tap, and well waters in Duguna Fango Woreda. Therefore, the objective of this study was to determine the level of fluoride ion in spring, tap, and well waters utilizing a fluoride ion-selective electrode and its physico-chemical properties, such as temperature, turbidity, pH, electrical conductivity, total hardness, total alkalinity, total solids, total suspended, and total dissolved solids in the selected area.

Materials and Methods

A description of the study area

This study was conducted in the Duguna Fango district of Wolita Zone, southern Ethiopia. The study area is situated 375 km southeast of the capital city of Addis Ababa (figure 1). The area lies within 037°35'30"- 037°58'36"E and 06°57'20 - 07°04'31"N. The number of people in the study area is 131,693 and it covers about 401.5 km2. The topographic elevation ranges from 1000 meters to 2500 meters above sea level. The average annual temperature varies from 17.6 to 22.5^0C over the region. The annual rainfall in the rift varies widely from around 800 mm in the rift to over 1,200 mm in large parts of the highlands, and the total water coverage of the district, including functional and non-functional, is 36.82%. The district has three agro-ecological zones: 23.3% woynadega (midland), 22.51% dega (high land), and 54.1% kola (low land).

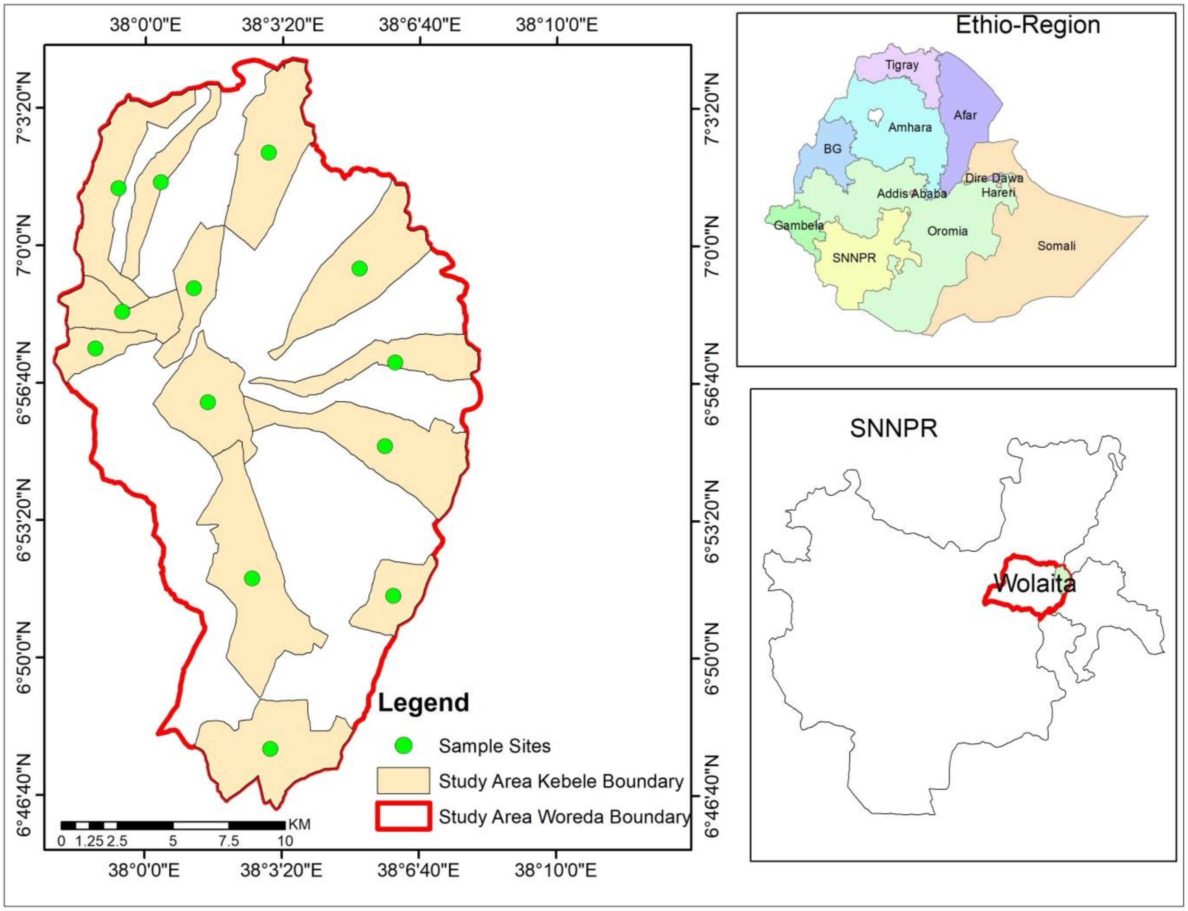

Figure 1: Map of the study area

Sample collection

Drinking water samples were collected from eleven different sites in the Duguna Fango district. A total of thirteen water samples were collected from each of the eleven sampling sites: five tap water, five spring water, and three well water samples. By using cleaned plastic polyethylene bottles, the samples are brought to the laboratory. Tap water samples were collected from Bilate Etta (Laygnaw Kamb), Bilate Charicho (Mender-16), Arusi Woyde (Arbina mender), Duguna Boloso (Gutara) and Karchache Mazegaja (Mender-1). Spring water samples were collected from Anka Damota (Dengele spring), Fango sore (Filo wuha), Bilate Dintu (Bilbo hot spring), Fango Humbo (Chille spring) and Waraza Lasho (Gelesho spring). Well water samples were collected from Fango Bijo (Ketena-1), Bilate Etta (Catholic Church) and Bilate Dintu (Catholic Church). Before the sampling, all the bottles were cleaned and rinsed thoroughly with distilled

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water. The sample bottles were capped and labeled with details of the source of water, time, and date of collection. The volumes of samples collected were sufficient for replicate analysis.

Laboratory analysis

The water samples were brought into the laboratory for the analysis of various physico-chemical parameters like temperature and pH, which were recorded at the time of sample collection by using a thermometer and a digital pH meter. The other parameters such as hardness, alkalinity, electrical conductivity, turbidity, total solids (TS), total dissolved solid (TDS), and totals suspended solid (TSS) were analyzed in the laboratory by using standard methods (Yasser and Gahwari, 2007). Standard methods were followed for sample collection and preservation. The samples, after collection, were transported on the sample date to the Arbaminch University, Department of Chemistry, for laboratory analysis.

Instruments and Apparatus

An ion-selective electrode meter equipped with a fluoride selective electrode was used for the determination of the fluoride level in the drinking water. The pH value was determined using a pH meter and an unfilled glass electrode. During the experiment, instruments such as a digital balance, burette, turbid meter, digital conductivity meter, polyethylene bottle, refrigerator, mercury thermometer, universal hot air oven, 50mL plastic beakers, watch glass, pipettes, magnetic stirrers, 50mL graduated plastic tubes, filter funnels, and filter papers were used.

Determination of fluoride in the water sample

The fluoride ion in the drinking water was analyzed directly by adding TISAB II buffer solution and taking the reading from a calibrated fluoride ion-selective electrode (Wang, 2003; Sun and Sun, 2007). Reagent blanks were prepared together with the samples through the procedure for blank determination. The purpose of the reagent blank was to correct for signals from sources other than the analyte, and the blank contains no deliberately added analyte (Malde et al., 2001). Finally, the fluoride ions in the drinking water sample were determined using a fluoride ion-selective electrode in Arbaminch University, chemistry laboratory, Ethiopia.

Determination of physico-chemical parameters of drinking water

The temperature of water samples was determined in the field due to their unstable nature. Water temperature measurements were made in degrees Celsius using a digital thermometer by directly dipping the thermometer in the natural body of drinking water. A mercury-filled centigrade thermometer calibrated from 0 ^{0}C to 100 ^{0}C was used for temperature measurements. The pH of each water sample was measured with a portable field pH meter (Guptaa, 2009).

Turbidity is a measure of the cloudiness of water. It measures the scattering effect suspended solids have on light; the higher the intensity of scattered light, the higher the turbidity. Primary contributors to turbidity include mud, silt, sand, small pieces of dead plants, bacteria, aquatic organisms, algae, and chemical precipitates. Turbidity is a key indicator used in assessing the suitability of water for human consumption. The turbidity of the water sample was measured using a turbid meter according to the international method of water quality measurement (Reda, 2016). Total alkalinity was measured by the titration method using a methyl orange indicator and titrating with standardized sulphuric acid (Obi and Okocha, 2007). Total hardness was measured by titration using EriochromeBlack T as an indicator and with a standardized EDTA solution (Reda, 2016). Electrical conductivity was measured using a digital conductivity meter model 4200 by shifting one of the four buttons of the instrument (Navneet et al., 2010).

Determination of Total Solid (TS)

A sample of the raw water was taken in a 100 mL beaker. A clean and dry crucible was weighed empty, and the sample was poured into it and re-weighed. The respective weights were recorded, and the crucible and sample water were then placed on a hot plate at 104 ^{0}C to evaporate the water. When all the water evaporated, the crucible was allowed to cool down and reweighed together with the residue. The total solid present was then calculated using the equation:

$$TS = 100\,(A - B)\,/\,200\,mL$$

Where A = weight of (crucible + water) -weight of crucible empty

B = crucible weight + residue

Determination of Total Suspended Solid (TSS)

It is defined as residue upon evaporation of a non-filterable sample on a filter paper. A sample of the raw water of 100 mL was taken in a sample bottle. The weight of a dry filter paper was depleted, and the sample water was filtered and the residue dried in an oven at 35–40 ^{o}C. The new weight of the filter paper plus residue was taken. The difference in the weight of the filter paper empty and with residue after drying was calculated and divided by the total sample volume.

$$TSS\ (mg/L) = (filter\ post\ weight - filter\ pre\ weight \times 100)\ /\ V\ sample\ (ml)$$

Determination of Total Dissolved Solid (TDS)

TDS refers to completely dissolved materials in water. These solids are filterable. It is defined as residue upon evaporation of a filterable sample. Total dissolved solids are those which get dissolved in water and cannot be separated from water by filtration. They may be chemically organic or inorganic. Total dissolved solids were obtained by taking the difference between TSS and TS using the conductivity meter.

Statistical analysis

Mean differences in the parameters between drinking water sources were statistically evaluated using a t-test, and one-way ANOVA and relationships between the fluoride and physico-chemical parameters were established using Pearson product-moment correlation coefficient (r) at a 5% significance level. The fluoride and physico-chemical parameters were compared with set standards, ICMR, and WHO guidelines for drinking water. The data analysis was done using Microsoft Excel 2007 and SAS (EFSA, 2013).

Results and discussion

Fluoride and selected properties of the drinking water from the study area

The mean values of the fluoride and selected physico-chemical parameters of the spring, tap, and well water samples and their comparisons among the water samples from different sources are summarized in Table 1. The means of the parameters that are indicated by similar letters are not statistically significantly different.

Fluoride content

This study showed that the measured value of fluoride ions in the drinking water samples ranged from 1.14 to 4.71 mg/L with a standard deviation of 0.8 mg/L. The result indicated that a relative minimum fluoride ion concentration was recorded in spring water samples from Fango Humbo (1.14 mg/L) and a maximum value of fluoride ion from Fango Sore and Waraza Lasho (4.71 mg/L); minimum tap water samples from Bilate Etta (1.47 mg/L) and a maximum value from

Arusi Woyde (3.94 mg/L); and minimum well water samples from Bilate Etta (1.80 mg/L) and a maximum value from Fango Boloso (3.84 mg/L).

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Table 1. Mean fluoride and selected properties of the spring, tap and well water samples in Duguna Fango woreda.

Place	Fluoride (mg/L)	pH	EC (µS/cm)	TURB (NTU)	TDS (mg/L)	TALK (mg/L)	THARD (mg/L)	TSS (mg/L)	TS (mg/L)	TEMP (^{0}C)
ADS	1.93^{e}	5.95^{e}	1171^{f}	9.46^{e}	609^{g}	215^{ed}	172.67^{d}	83.67^{e}	41.33^{h}	26.5^{e}
BDS	1.99^{ed}	6.99^{bc}	2926^{b}	10.7^{dce}	2016.33^{b}	291.67^{b}	179 d	87.67^{ed}	108^{e}	36^{a}
FHS	1.14^{g}	6.21^{de}	845.67^{g}	11.6^{dce}	475.67^{h}	179.67^{f}	110.33^{g}	103.33^{c}	124.67^{d}	25.5^{fg}
FSS	4.69^{a}	7.56^{a}	2412.67^{dc}	16.4^{c}	1514.67^{ed}	261.67^{c}	301.67^{c}	70.33^{f}	125^{d}	30.5^{d}
WLS	4.71^{a}	4.87^{f}	4046.33^{a}	106.27^{a}	331^{i}	206.67^{e}	167.67^{g}	170^{a}	209^{a}	24.5^{h}
AWT	3.94^{b}	6.94^{bc}	769.67^{g}	10.34^{de}	382.67^{i}	205^{e}	166.67^{g}	110^{cb}	93.33^{f}	26^{fe}
BCT	2.94^{c}	6.43^{d}	1810.33^{e}	15.95^{dc}	1027.33^{f}	221.67^{d}	383.33^{a}	121.67^{b}	161.67^{b}	25^{hg}
BET	1.47^{f}	6.57^{dc}	2544^{c}	8.6^{e}	1562^{d}	295^{b}	345^{b}	77.67^{ef}	162.33^{b}	26^{fe}
DBT	2.11^{ed}	7.24^{ba}	3078^{b}	10.57^{dce}	307^{i}	205^{e}	101^{h}	98.67^{cd}	92.67^{f}	25.5^{fg}
KMT	1.83^{e}	6.65^{dc}	795.67^{g}	10.29^{de}	379^{i}	183^{f}	244.33^{e}	55^{g}	105^{fe}	24.17^{h}
BDW	2.31^{d}	7.36^{ba}	3026.67^{b}	10.5^{de}	1858.33^{c}	291.33^{b}	172.33^{d}	105^{c}	144^{c}	33^{b}
BEW	1.8^{e}	7.2^{ba}	2974^{b}	28.84^{b}	2463.33^{a}	308.67^{a}	272.33^{d}	173^{a}	67^{g}	31.5^{c}
FBW	3.84^{b}	7.64^{ba}	2289.33^{d}	12.19^{dce}	1479^{e}	209^{ed}	200.67^{f}	67.33^{f}	202.67^{a}	30.8^{d}
Av. Mean	2.67	6.71	2206.87	20.13	1108.18	236.41	216.7	101.8	125.9	28.11
LSD	0.61	0.67	567.23	8.68	258	31.08	32	19	11.02	0.06

Note: ADS= Spring water from Anka Damota, BDS= Spring water from Bilate Dintu, FHS= Spring water from Fango Humbo, FSS= Spring water from Fango Sore, WLS= Spring water from Waraza Lasho, AWT= tap water from Arusi Woyde, BCT= Bilate Charicho tap, BET= tap water from Bilate Etta, DBT= tap water Duguna Boloso from, KMT= tap water from Karchache Mazegaja, BDW= well water from Bilate Dintu, BEW= well water from Bilate Etta, FBW= well water from Fango Bijo. LSD is an abbreviation for least significant difference.

The floride content in drinking water showed statistically significant differences ($P < 0.05$) among most water sources. The average mean values of fluoride ions in spring, tap, and well water were found to be 2.88, 2.46 mg/L, and 2.65 mg/L, respectively (figure 2). The mean separation method showed that the fluoride levels of spring water of Anka Damota and Bilate Dintu with tap water of Bilate Eta, Duguna Boloso, Karchache Mazegaja and well water of Bilate Eta; spring water of Bilate Dintu with tap water of Duguna Boloso and well water of Bilate Dimtu; spring water of Fango Sore with Waraza Lasho; and tap water of Arusi Woyde with well water of Fango Bijo are statistically at par ($P > 0.05$). However, the fluoride ion in Fango Humbo is statistically significantly different from others ($P < 0.05$) (Table 1). These significant differences may be due to differences in the physicochemical properties of water and require site-specific treatment of fluoride in drinking water. Also, the fluoride content in drinking water was strongly positively correlated with TURB and TS, having Pearson correlation coefficients of 0.506 and 0.463, respectively (Table 3).

The measured value of fluoride ion in spring water was higher than the levels of fluoride ion in tap and well water samples. The presence of fluoride compounds in the underground water might be responsible for the higher value of the fluoride ion. The measured value of fluoride ion in all drinking water was above the critical values of fluoride ion recommended by WHO (1.5 mg/L) and ICMR (1 mg/L), but Fango Humbo spring (1.14 mg/L) and Bilate Eta well (1.80 mg/L) were within the maximum standard value of fluoride ion in drinking water set by WHO and above the ICMR (1 mg/L). As noted by NRC (2006), the evidence indicates that the threshold for severe dental fluorosis occurs at a water fluoride level of about 2 mg/L. The result of this study confirmed that the drinking water in the study area is not safe for consumption regarding the level of fluoride ions. Rango et al. (2012), reporting the result of this study, reported that the fluoride content in drinking water around Ziway exceeded the WHO drinking water guideline limit of 1.5 mg/L.

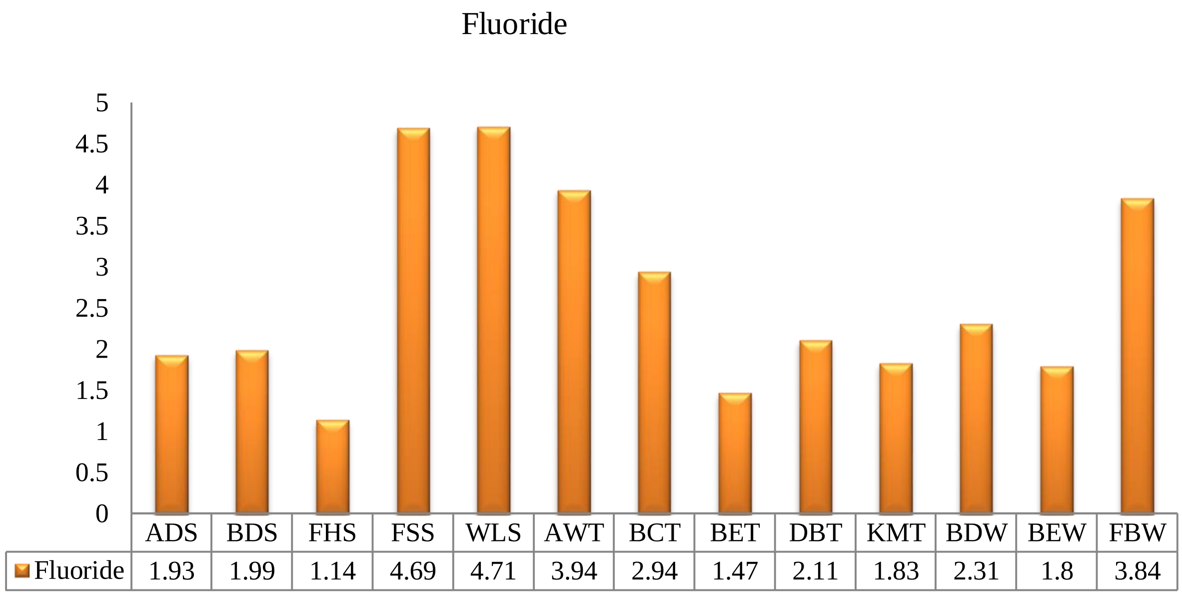

Figure 2: The level of fluoride in the drinking water of the study area

The temperature of the water in the study area

As shown in Table 1, the highest mean temperature was recorded in spring water from Bilate Dintu (36 ^{0}C); however, people use this water for drinking purposes after cooling it with locally available materials like a pot (a pitcher). The lowest temperature was recorded in the Karchche Mazegaja tap (24.17 ^{0}C) (Figure 3). Spring water temperatures ranged from 24.5 0C to 36 0C, while tap water temperatures ranged from 24.17 0C to 25.5 0C and well water temperatures ranged from 30.83 0C to 33 0C. The average mean temperature value is 28.12 ^{0}C with a standard deviation of 1.2 ^{0}C. However, all the recorded water temperatures of the drinking water sources in the study area were found to be above the critical value suggested by WHO (<15 ^{0}C) (WHO, 1996). This high temperature of drinking water in the study area might be due to the climatic condition of the area because Duguna Fango is found in the central rift valley area. The drinking water in the study area is not safe because temperatures greater than 15 0C have been associated with biofilm formation in drinking water distribution systems (Reimann et al., 2003). This showed that the temperature of all drinking water samples was higher than the permissible limits, and the potable water was not safe in terms of temperature. Also, high water temperature enhance the growth of microorganisms and may increase taste, odor, color, and corrosion problems (WHO, 2006). The mean separation method showed that the temperature of drinking water from most sites was statistically significantly different (Table 1). These differences may be due to differences in climatic conditions that call for site-specific water treatment.

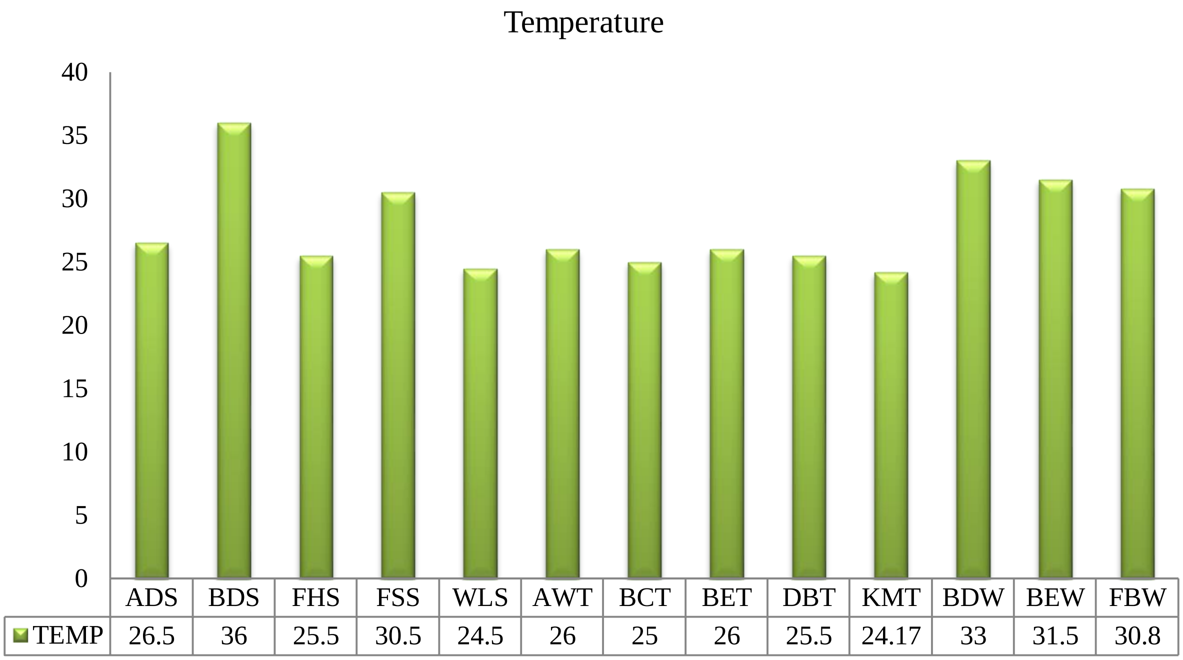

Figure 3: Temperature in the study area's drinking water

The pH of the drinking water in the research areas was determined.

The result of the present study revealed that the measured values of pH in the drinking water samples ranged from 4.87 to 7.56 mg/L with a standard deviation of 0.26. The result of this study indicated that a relative minimum pH value was recorded in spring water samples from Waraza Lasho (4.87), which can have the potential to cause any harmful effect on the consumers and the maximum value of pH from Fango Sore (7.56), minimum tap water samples from Bilate Charicho (6.43), the maximum value from Duguna Boloso (7.24), and minimum well water samples from Bilate Etta (7.2) and the maximum value from Bilate Dintu (7.36) (Figure 4). The mean values of pH in spring, tap, and well water were found to be 6.32, 6.77, and 7.29, respectively. This shows that the pH of spring water samples (6.32) was below the recommended range but the tap and well range obtained for the samples were within the acceptable limit of WHO and national standards, which is from 6.5 to 8.5 (WHO, 2004). The pH of drinking water has no immediate direct effects on human health but has some indirect health effects by bringing

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changes in other water quality parameters such as solubility of metals and survival of pathogens (WHO, 2008). The mean separation methods showed that the pH values of spring water of Anka Damota, Fango Humbo, and Bilate Dintu with tap water of Arusi Woyde, Duguna Boloso, and well water of Bilate Dintu, Bilate Eta, and Fango Bijo, spring water of Fango Sore with tap water of Duguna Boloso, well water of Bilate Dintu, Bilate Eta, and Fango Bijo were statistically the same, but Waraza Lasho was found to be statistically different. Table 3 showed that pH of the drinking water was negatively correlated with EC, TSS and TS ($P < 0.05$) ($r = -0.036$, $r = -0.364$ and $r = -0.171$), strong and perfect negative linear relationship with TURB ($r =-0.649$), and a strong positive correlation with TDS and TEMP ($r = 0.488$ and $r = 0.536$), respectively.

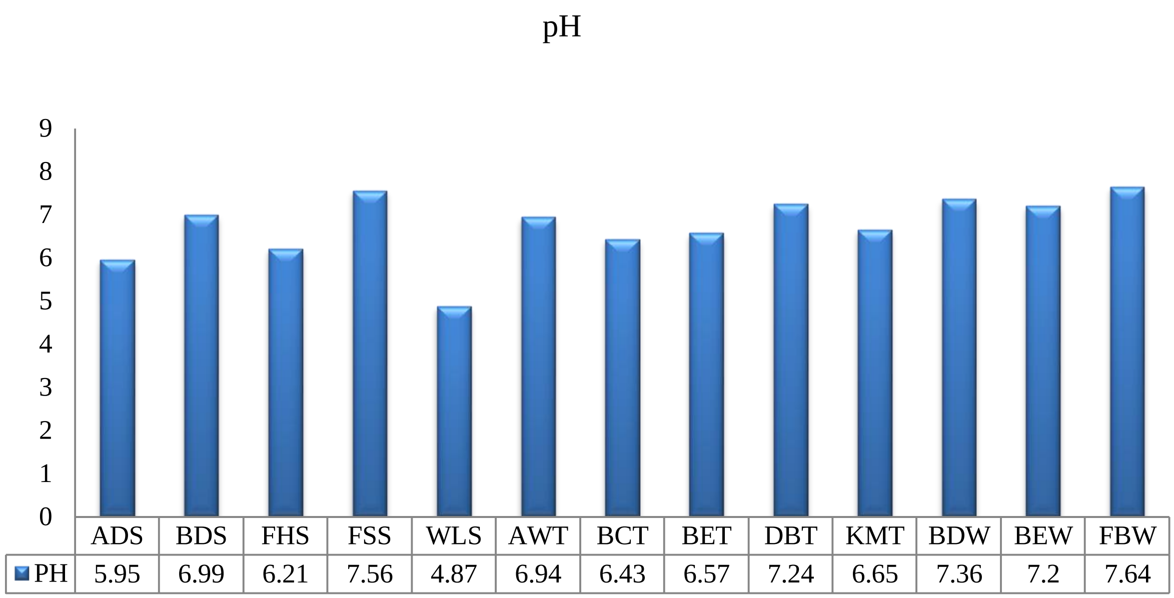

Figure 4: The value of pH in the drinking water of the study area

Electrical conductivity (EC)

The EC values of the drinking water samples analyzed in the laboratory ranged from 769.67 to 4046.33 μS/cm. A high electrical conductivity value was recorded from Waraza Lasho spring water sources and low conductivity from Arusi Woyde tap water. The mean conductivity of spring water ranged from 845.67 to 4046 μS/cm; the conductivity of tap water ranged from 769.67 to 3078 μS/cm and the conductivity of well water ranged from 2289.33 to 3026.67 μS/cm, which was outside the ranges of conductivity. The average mean value of EC was found to be 2206.87 μS/cm with a standard deviation of 341.6 μS/cm. According to WHO (2008), conductivity values of all water samples were found to be in the permissible range (769.67–4046.33 μS/cm). However, it was observed that there was a significant variation in electrical conductivity from site to site (Table 1).

Total alkalinity

The result of this study indicated that a relative minimum alkalinity value was found in spring water samples from Fango Humbo (179.67 mg/L) and the maximum value from Bilate Dintu (291.67 mg/L); minimum tap water samples from Karchache Mazegaja (183 mg/L) and the maximum value from Bilate Etta (295 mg/L); and minimum well water samples from Fango Bijo (209 mg/L) and the maximum value from Bilate Eta (308.67 mg/L). The average mean value of total alkalinity in spring, tap, and well water was found to be 230.93, 221.93, and 269.67 mg/L, respectively. Fango Humbo spring had the lowest mean total alkalinity (179.67 mg/L) and Bilate Eta well water had the highest (295 mg/L). The laboratory analysis results showed that the total alkalinity concentration in well water was higher as compared to the levels of total alkalinity in spring and tap water samples. The alkalinity levels in drinking water samples from the majority of sources in the study area were found to be higher than the acceptable limit (200 mg/l) (WHO, 2008).

Total hardness

The result of this study revealed that a relative minimum total hardness value was obtained in spring water samples from Fango Humbo (110.33 mg/L) and a maximum value from Fango Sore (301.67 mg/L); minimum tap water samples from Duguna Boloso (101 mg/L); a maximum value from Bilate Charicho (383.33 mg/L); and minimum well water samples from Bilate Dintu (172.33mg/L); and a maximum value from Bilate Etta (272.33 mg/L) for the entire water samples analyzed. The average mean value was 216.69 mg/L with a standard deviation of 0.56 mg/L. Durfor and Becker (1964) determined that the majority of the drinking water samples from the study area were in the moderate to hard category. The highest value of total hardness was observed in Bilate Charicho and the lowest in Duguna Boloso. According to the above classification, all water samples are hard, but all measured values are within the BIS (300 mg/L) and WHO (500 mg/L) acceptable limit values.

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Total dissolved solids

Total dissolved solids are important indicators of drinking water quality because they can affect other drinking water characteristics such as taste, hardness, and turbidity. It has been reported that the amount of TDS is more than 500 mg/l, which is not recommended as desirable for drinking water supplies but in some special cases will be allowed up to 1500 mg/l (WHO, 2008). In this study, the values of TDS of analyzed spring, tap, and well water samples varied between 331 and 2016.33, 307.00 to 1562.00, and 1479.00 to 2463.33 mg/L, respectively. The highest TDS value was observed in Bilate Eta well water (2463.33 mg/L) and the lowest value in Duguna Boloso tap water (307 mg/L). This might be due to the difference in their sources. The average mean value is 1108.18, with a standard deviation of 242.6. However, all the values were found to be above the standard limit of WHO and ICMR (500 mg/L). Therefore, the drinking water of the study area is not safe in terms of TDS.

The total dissolved solids of spring water of Fango Sore with well water of Fango Bijo and tap water of Bilate Eta, spring water of Waraza Lasho with tap water of Arusi Woyde, Duguna Boloso, and Karchache Mazegaja are significantly similar ($P>0.05$), but all others are different ($P< 0.05$). The total hardness of spring water of Anka Damota, Bilate Dintu, Waraza Lasho, and Fango Humbo with tap water of Arusi Woyde and well water of Bilate Dintu with Bilate Eta were found to be statistically similar, but all others were significantly different.

TSS (Total Suspended Solids)

The relative minimum TSS value was recorded in spring water samples from Fango Sore (70.33 mg/L), while the maximum value was recorded in Waraza Lasho (170 mg/L); minimum tap water samples from Karchache Mazegaja (55 mg/L), while the maximum value was recorded in Bilate Charicho (121.67 mg/L); and minimum well water samples from Fango Bijo (67.33 mg/L), while the maximum value was recorded in Bilate Etta (173 mg/L). The average mean value of TSS in spring, tap, and well water was found to be 103, 92.6, and 115.11 mg/L, respectively. The highest TSS value was observed in Bilate Etta well water (173mg/L) and the lowest value in Duguna Karchache Mazegaja tap water (55 mg/L). The average mean value is 101.8 mg/L with a standard deviation of 11.8 mg/L. This indicates that the measured value of TSS in drinking water was higher than the WHO standard value of TSS in drinking water (30 mg/L) but lower than the ICMR expected value of 500 mg/L.

Total solids (TS)

The TS values of water samples were found to be between 41.33 and 125, 92.66 and 162.33, and 67 and 202.67 mg/L in spring, tap, and well water samples, respectively, according to laboratory analysis. The average mean value of TSS in spring, tap, and well water was found to be 103, 92.6, and 115.11 mg/L, respectively. Fango Bijo well water had the highest TS value (202.67 mg/L) and Anka Damota well water had the lowest (41.33 mg/L). The average mean value is 125.9, with a standard deviation of 16.2. All these measured values were also within the WHO guideline value, which is 500 mg/L. The results of TS showed that drinking water doesn't cause health problems for consumers.

Turbidity

The turbidity value of the spring water varied from 9.46 to 106.27 NTU, that of tap water from 8.6 to 15.95 NTU, and that of well water from 10.5 to 28.84 NTU. The highest turbidity value was observed in Waraza Lasho spring (106.27 NTU), which has a red color, and the lowest value was observed in Bilate Eta (8.6 NTU). The average mean value is 20.14, with a standard deviation of 8.6. Turbidity can vary from location to location due to human activity, rising water levels, and the presence of dissolved particulate matter. In this study, all the water samples were high in turbidity. This might be due to diverse and many constituent particles (e.g. clays, soils, and natural organic matter) that can also indicate the presence of hazardous chemical and microbial contaminants and have significant implications for water quality (WHO, 2006).

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Table 2. Correlation between fluoride and selected physico-chemical parameters of drinking water samples

	Fluoride	PH	EC	TURB	TDS	TALK	THAR	TSS	TS	TEMP
Fluoride	1									
PH	-.050	1								
EC	.262	-.036	1							
TURB	.506**	-.649**	.566**	1						
TDS	-.131	.488**	.417**	-.199	1					
TALK	-.263	.000	-.141	-.075	.028	1				
THARD	.087	.094	.005	-.095	.407*	-.146	1			
TSS	.136	-.364*	.465**	.661**	.104	.070	-.045	1		
TS	.463**	-.171	.400*	.460**	.007	-.062	.206	.052	1	
TEMP	-.007	.536**	.381*	-.225	.829**	.009	-.031	-.045	-.072	1

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

Comparison of fluoride levels and selected physico-chemical parameters of the study area with critical levels

The comparison of the fluoride concentration in drinking water samples determined in the current study and those reported in the literature is presented in Table 3. The level of fluoride in drinking water samples of this study (2.67 mg/L) is greater than that of the WHO critical level (1.5 mg/L) and the ICMR standard (1 mg/L). The pH value of drinking water samples (6.71) in this study is comparable to that reported by WHO and ICMR (6.5–8.5). The values of electrical conductivity (2206.87 μS/cm), turbidity (20.13 NTU), total dissolved solids (1108.18 mg/L) and total alkalinity (236.41 mg/L) are much higher than those reported by WHO and ICMR standards. The total hardness of the water sample (216.71mg/L) was much lower than that of the WHO standard (5001mg/L) and the ICMR standard (3001mg/L). The sample's total suspended solids (101.81mg/L) were higher than the WHO standard (301mg/L) but much lower than the ICMR standard (500).

The possible reasons for the different levels of fluoride and selected physico-chemical parameters in the drinking water samples might be due to the difference in topographical location; difference in mineral contents of soil and atmosphere; variation in the application of agrochemicals like fertilizers, pesticides, herbicides, etc.; or other variations in the brewing process between groups of samples.

Table 3. Comparison of fluoride levels and selected physico-chemical parameters of this study with literature values

Parameters	WHO standard	ICMR standard	Present study			Average mean
			Spring water	Tap water	Well water	
Fluoride	1.5	1	2.88	2.46	2.65	2.67
PH	6.5 – 8.5	6.5 – 8.5	6.32	6.77	7.29	6.71
Electrical conductivity(EC)	400	300	2280.33	1799.53	2763.33	2206.87
Turbidity	6	5	30.89	11.15	17.18	20.13
Total dissolved solid(TDS)	500	500	989.33	735.53	1933.56	1108.18
Total alkalinity(TA)	200	200	230.93	221.93	269.67	236.41
Total hardness(TH)	500	300	186.27	248.07	215.11	216.7
Total suspended solid(TSS)	≤30	500	103	92.6	115.11	101.8
Total solid(TS)	500	-	121.6	123	137.89	125.9
Temperature	15	-	28.6	25.3	31.8	28.12

Source: (Reda AH, 2006)

Conclusions

From the result of this study, it can be concluded that almost in all drinking water samples, fluoride levels and analyzed values of selected physicochemical parameters were out of permissible levels as per either the Ethiopian compulsory standard, ICMR standard, or WHO guideline values. The average mean result indicates that the pH values from spring and tap water, total solids, total hardness, and TSS from spring, tap, and well water samples were within the acceptable range. On the other hand, measured values from the laboratory analysis, especially fluoride, temperature, turbidity, electrical conductivity, TDS, and total alkalinity in spring, tap, and well water samples, were recorded as maximum and outside of the recommended limit.

As the result of this study indicated, a high turbidity level of water indicates water that lacks the transparency of ions and other important substances, which are important for drinking as well as for plants and animals that live inside the body of water. Similarly, a high turbidity level indicates there exists a high amount or level of suspended solids in water bodies. The total alkalinity value of the district was recorded as being greater than the standard values. The maximum level of alkalinity may indicate that drinking water or any other water contains nutrients contributing to alkalinity like OH^-, CO_3^{2-}, and HCO_3^-, but from the laboratory result, the pH value of spring and tap water recorded was below 7.0, which is not basic. This may indicate nutrients contributing to alkalinity may be due to $CO_3^{2-}$and HCO_3^-. Most drinking water samples from villages showed fluoride and selected physico-chemical parameters above the water quality standards. The quality of water is very bad and it is unfit for drinking purposes. Therefore, the water sources in the study area need sustainable remedial action to make them safe for drinking.

Abbreviation

ANOVA stands for Analysis of Variance; ATSDR stands for the Agency for Toxic Substances and Disease Registry. CDTA stands for Cyclohexylene Dinitrilo Tetra Acetic acid, DL stands for Detection Limit, and EC stands for Electrical Conductivity. EDTA stands for Ethylene Diamine Tetra Acetic Acid. EFSA is an abbreviation for the European Food Safety Authority; EMoWR is an abbreviation for the Ethiopian Ministry of Water Resources; ICMR is an abbreviation for the Indian Council of Medical Research; and IPCS is an abbreviation for the International Program on Chemical Safety. ISE stands for Ion Selective Electrode; NRC stands for National Research Council; NTU stands for Nephelometric Turbidity Unit; and TDS stands for Total Dissolved Solid. TISAB stands for Total Ionic Strength Adjustment Buffer; TSS stands for Total Suspended Solid; and WHO stands for World Health Organization.

Ethical clearance

Ethical clearance was not required for this particular research because it did not include animals or plants.

Consent to publication

This research work did not involve human subjects for experimental purposes, and they gave informed consent to participate in the study.

Availability of data and materials

Data generated during this research work can be available upon request.

Competing interests

The authors declare that they have no competing interests.

Funding

No financial support has been obtained for this study.

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